Technical Efficiency and Determinants of Khao Gor Kor – Maejo 2 Rice Production: Insights from Stochastic Frontier Modeling

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Abstract

This study investigates the technical efficiency of Khao Gor Kor – Maejo 2 rice production in Chiang Rai province, Thailand, using the Stochastic Frontier Approach (SFA) to identify key factors influencing efficiency. Despite the introduction of improved rice varieties like Khao Gor Kor – Maejo 2, many smallholder farmers struggle to achieve optimal productivity, hindered by inefficiencies in input utilization and resource management. Primary data were collected from 400 rice farmers through structured interviews, and the SFA model was applied to estimate technical efficiency scores and determine the sources of inefficiency. The study concludes that optimizing capital and labor inputs and addressing inefficiencies through targeted interventions could substantially improve the technical efficiency of Khao Gor Kor – Maejo 2 rice production. These insights are critical for developing policies and strategies that enhance agricultural productivity and sustainability, ultimately benefiting smallholder farmers and contributing to food security in Thailand. Future research is recommended to explore additional variables and extend the analysis to other rice varieties and regions.

Keywords: Khoa Gor Kor-Maejo2; Stochastic Frontier; Technical Efficiency

1. Introduction

Rice, particularly Khao Gor Kor-Maejo2 (KGK-MJ2), is a staple food and a significant economic crop in Thailand. Its cultivation is crucial for ensuring food security, generating rural incomes, and supporting the national economy. However, despite its importance, the

production efficiency of KGK-MJ2 has been a subject of growing concern due to factors such as resource constraints, climate change, and changing market dynamics. Enhancing the technical efficiency of KGK-MJ2 production is therefore imperative for the sustainability of the rice sector. The specific problem addressed in this study is the need to identify and quantify the factors that influence the technical efficiency of Khao Gor Kor – Maejo 2 rice production. Understanding these factors is crucial for developing strategies to enhance productivity and ensure the sustainable use of resources. While previous studies have examined technical efficiency in rice production, there is limited research focused on this specific rice variety, especially in the context of smallholder farming systems in Thailand.

This study addresses these research gaps by focusing specifically on the technical efficiency of Khao Gor Kor – Maejo 2 rice production, using the Stochastic Frontier Approach to identify and analyze the key factors influencing efficiency. By concentrating on smallholder farmers and providing policy-oriented insights, the research aims to contribute valuable knowledge that can inform strategies for enhancing rice production efficiency in Thailand. Technical efficiency, defined as the maximum output attainable from a given set of inputs, is a crucial metric for evaluating the performance of agricultural systems. Several studies have explored the technical efficiency of rice production across various regions of Thailand, highlighting key factors that influence productivity. For example, Wiboonpongse, Sriboonchitta, and Chaovanapoonphol (2006) analyzed the technical efficiency of rice farmers in Northern Thailand using a stochastic frontier approach, revealing significant inefficiencies due to suboptimal use of inputs and traditional farming practices. Their study suggests that efficiency could be improved through better resource management and adoption of modern techniques. Coelli and Fleming (2004) conducted a study on rice farmers in Southern Thailand, finding that differences in technical efficiency were closely related to access to irrigation and capital. They emphasized the importance of infrastructure development in enhancing agricultural productivity. Kumar and Singh (2008) studied rice production efficiency in the Central Plains and found that farm size, education level of the farmer, and access to extension services significantly impacted efficiency levels. Coelli et al. (2005) examined the efficiency of rice farmers in Bangladesh, finding significant variations in efficiency levels due to differences in input use, access to technology, and farming practices. Autchariyapanitkul et al. (2017) applied a Stochastic Frontier Model (SFM) using a Generalized Maximum Entropy (GME) approach, which offers a more accurate estimation of inefficiency compared to conventional methods. Their analysis revealed that 95% of the sampled sticky rice farmers exhibit high inefficiencies, with most efficiency scores falling between 0.6 and 0.8. Collectively, these studies demonstrate the need for region-specific strategies to improve the technical efficiency of rice production across Thailand. While these studies provide valuable insights, there is still a need for further research to understand the specific challenges and opportunities in KGK-MJ2 production.

This study aims to contribute to this body of knowledge by analyzing the technical efficiency of KGK-MJ2 production in Chiang Rai. The research will focus on identifying factors affecting efficiency. By employing Stochastic Frontier Analysis (SFA), this study seeks to provide empirical evidence on the factors influencing technical efficiency and to offer recommendations for improving the productivity of KGK-MJ2 farmers. The findings of this research are expected to inform policymakers, extension services, and farmers about the potential areas for enhancing KGK-MJ2 production. By identifying the key determinants of technical efficiency, this study can contribute to the development of targeted interventions to improve resource utilization, reduce production costs, and increase farm incomes. Ultimately, this research aims to support the sustainable development of the KGK-MJ2 sector in Thailand.

2. Research Objectives

The objective of this study is to evaluate the technical efficiency of Khao Gor Kor-Maejo 2 rice production specifically in Chiang Rai province.

3. Research Methodology

3.1 Data Collection

Data were collected through structured interviews using a questionnaire. The questionnaire was designed to gather information on various aspects of rice production, including demographic details, input usage (seeds, fertilizers, labor), and output (rice yield). The questionnaire was pre-tested on a small group of farmers to ensure clarity and relevance, and necessary adjustments were made based on feedback. Due to the exact population number is unknown. Therefore, the sample size can be calculated from W.G.Cochran's unknown sample size formula given a 95 percent level of significant. Using this formula, the calculated sample size is approximately 384 farmers. To account for potential non-responses or incomplete data, the sample size was increased to 400 farmers.

3.2 Variables

The key variables examined in this study include: Dependent Variable such as Rice Yield (kg): The output of rice production per farmer. Independent Variables including Seed Usage (kg): The number of seed used per plot. Labor Cost (THB): The total cost of labor used in rice production. Fertilizer Cost (THB): The total cost of fertilizers used. Pesticide Cost (THB): The total cost of pesticides used. Irrigation Zone: Categorical variable indicating whether the farm is within or outside an irrigation zone. Soil Characteristics: Categorical variable indicating the type of soil (sandy loam, clay, clay loam).

3.3 Stochastic Production Frontier (SPF) Approach

The Stochastic Production Frontier approach was first introduced by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977) This method allows for the separation of random noise from inefficiency effects in production, making it particularly suitable for analyzing agricultural data, where unpredictable factors such as weather can influence output. The SPF model has since been widely adopted in agricultural economics to assess the efficiency of various crops and farming systems. Battese and Coelli (1995) further developed the SPF model by introducing a method to estimate inefficiency effects in a panel data setting, which allowed for a more nuanced understanding of the factors influencing technical efficiency over time. Their work has laid the foundation for numerous studies on agricultural efficiency, particularly in developing countries where variability in farming practices and environmental conditions is significant.

Stochastic Frontier Analysis (SFA) is a statistical method used to estimate the production frontier and measure technical inefficiency in economic production processes. Unlike deterministic frontier models, SFA incorporates a random error term to account for statistical noise and a non-negative inefficiency term to capture the extent to which firms or individuals operate below their maximum potential. The basic SFA model can be expressed as follows:

$$y = f(x) + v + u$$

where:

y is the observed output

$f(x)$ is the production frontier function, representing the maximum possible output given the input vector x

v is a symmetric random error term, representing statistical noise

u is a non-negative inefficiency term, capturing the deviation from the production frontier

The production frontier function f(x) is typically specified as a Cobb-Douglas or translog functional form. The inefficiency term u is often assumed to follow a half-normal or truncated normal distribution.

4. Research Findings Summary

This study on the technical efficiency of Khao Kao Maejo 2 rice production aimed to achieve two primary objectives: 1) to analyze the technical efficiency of Khao Kao Maejo 2 seed production, and 2) to examine the relationship between production factors and the yield of Khao Kao Maejo 2 rice. Primary data were collected from a sample of 400 farmers in Chiang Rai province in 2020. The research findings are as the following

4.1 General Information of Farmers

General Information	Number (persons)	Percentage (%)
Gender		
Male	303	75.75
Female	97	24.25
Total	400	100.0
Age (years)		
Equal or below 30	3	0.75
31 – 37	9	2.75
38 – 44	27	6.75
45 – 51	64	16.00
Equal or above 52	297	74.25
Total	400	100.00
Education		
Primary school	297	74.25
Junior High School	30	7.5
Senior High School	48	12.00
Vocational School	16	4.00
Undergraduate	9	2.25
Total	400	100.00
Irrigation Zone		
Outside the irrigation zone	84	21.0
Inside the irrigation zone	316	79.0
Total	400	100.00
Cultivated Area		
Lowland	51	12.75
Upland	349	87.25
Total	400	100.00
Soil Characteristics		
Sandy Loam Soil	124	33.5
Clay Soil	120	30.0
Clay Loam Soil	146	36.5
Total	400	100.00

Table 1 General Information of Farmers

An analysis of the general characteristics of the farmers revealed that the majority were male, accounting for 75.75% of the respondents (303 individuals), while females made up the remaining 24.25% (97 individuals). Most rice farmers were 52 years old or older, with 74.25% of the farmers (297 individuals) falling into this age group. The majority of farmers had completed only primary education (74.25%).

Regarding the cultivation area, most of the land used to grow Khao Kao Maejo 2 rice was upland, accounting for 87.25% of the total area, with the remaining 12.75% being lowland. Furthermore, a significant proportion of the cultivated land (79%) was under irrigation, while 21% was non-irrigated. Soil types were fairly evenly distributed among the farmers: 36.5% of the land was clay loam, 33.5% was sandy loam, and 30% was clay.

4.2 Summary Statistics of Rice Cultivation

Table 2 presents the summary statistics for various inputs and outputs related to rice cultivation based on a sample of 400 observations. The variables include the quantity of seeds used, the costs associated with pesticides, fertilizers, and labor, and the yield of rice production.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Seed (kilograms)	400	295.01	130.91	84	1,840
Pesticide Cost (THB)	400	318.35	83.56	44	445
Fertilizer Cost (THB)	400	355.01	565.39	0	7,420
Labor Cost (THB)	400	1,653.53	813.41	600	11,969
Yield (kilograms)	400	616.36	164.59	20	1,000

Table 2 Summary Statistics of General Information on Rice Cultivation

This summary provides a concise overview of the variability and central tendencies in the data, which is critical for understanding the distribution of inputs and outputs in rice cultivation.

4.3 Analysis of Production Efficiency Using Stochastic Production Frontier

The analysis of production efficiency was conducted using the Stochastic Production Frontier technique, with parameter estimation carried out using the Maximum Likelihood method. The objective was to assess the technical efficiency of producing the rice variety "Khao Kao Maejo 2" by applying a Cobb-Douglas production function to identify the factors influencing production efficiency. The Cobb-Douglas (CD) Production Function (Cobb, C. W., & Douglas, P. H. ,1928) is a widely used functional form in economics to represent the relationship between inputs (typically capital and labor) and the output of a firm or economy. Table 3 presents the results of the estimation, showing the coefficients, standard errors, t-statistics, and p-values for each variable.

Variable	Coefficient	Std. Err.	t-stat	p-value
Capital	-0.0213***	6.35e-06	-0.0003	0.000
Labor Cost	0.0175***	5.66e-06	-3,106.91	0.000
Constant	7.960	0.0000134	590,000	0.000
σ_v	1.13e-08	1.16e-06		
σ_u	0.811	0.02667		
λ	7.18e+07	0.02867		

Notes: significant at 0.05 level of significant.

Table 3 Factors Influencing Production According to Cobb-Douglas Theory

The results from the Cobb-Douglas production function analysis reveal that labor cost has a positive and statistically significant impact on production, while capital unexpectedly shows a negative effect. The coefficient for labor cost (0.0175) suggests that higher labor expenses contribute to increased production, possibly indicating that labor investment enhances productivity. Conversely, the negative coefficient for capital (-0.0213) is counterintuitive, as capital is generally expected to boost production. This result may stem from model mis-specification, diminishing returns, omitted variables, or data-related issues. The variance parameters further indicate that inefficiencies play a significant role in production, with λ (7.18e+07) suggesting that inefficiencies dominate over random fluctuations. The findings imply that firms should focus on improving labor productivity while reassessing capital investments to avoid inefficiencies. Given the unexpected negative impact of capital, further analysis is recommended, including testing for multicollinearity, exploring alternative production function specifications, and reassessing capital measurement to ensure robust conclusions.

4.4 Technical Efficiency Distribution

Technical Efficiency (TE: %)	Number of Farmers	Percentage (%)
0-20	11	2.75%
21-40	2	0.5%
41-60	191	47.75%
61-80	139	34.75%
81-100	57	14.25%
Total	**400**	**100%**

Table 4 Technical Efficiency of Farmers in Rice Production for the Khao Khao-Maejo 2 Variety

This table illustrates the distribution of technical efficiency among farmers in the production of the Khao Khao-Maejo 2 rice variety.

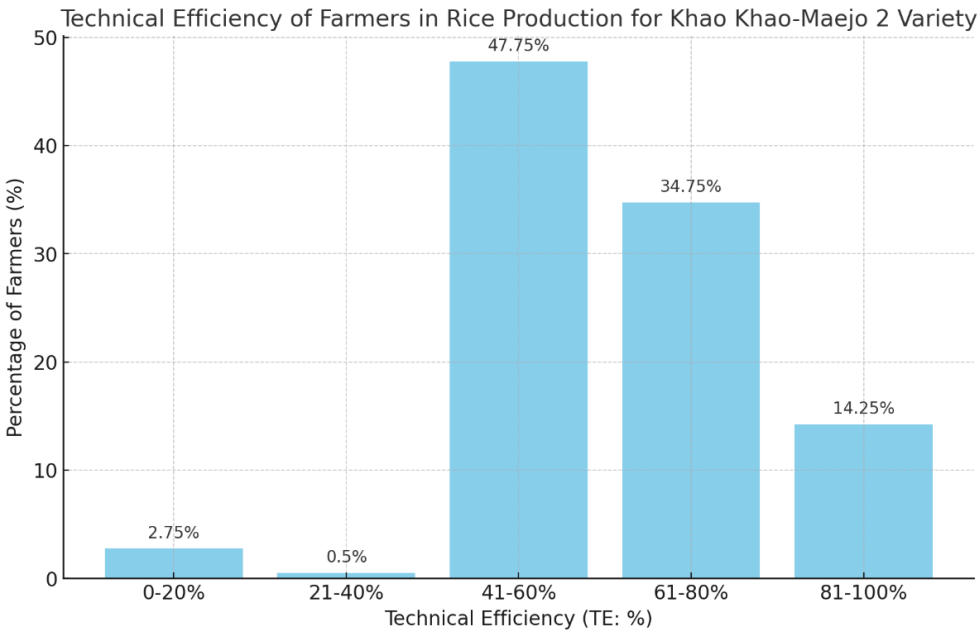


Figure 1 Technical Efficiency of Farmers in Rice Production for Khoa Khao-Maejo 2 Variety

The accompanying graph displays the distribution of farmers' technical efficiency in producing the Khao Khao-Maejo 2 rice variety. The technical efficiency (TE) is categorized into five ranges: 0-20%, 21-40%, 41-60%, 61-80%, and 81-100%. The y-axis represents the percentage of farmers within each efficiency range.

The analysis of technical efficiency (TE) among farmers reveals that the majority, approximately 47.75%, operate within the 41-60% efficiency range, indicating moderate efficiency levels in rice production. This suggests that nearly half of the farmers have room for improvement in optimizing their resources. The second-largest group, comprising about 34.75% of farmers, falls within the 61-80% efficiency range, demonstrating relatively high efficiency but still leaving potential for further enhancement. A smaller but notable proportion, around 14.25%, achieves high technical efficiency in the 81-100% range, indicating that these farmers are utilizing their resources effectively and maximizing their production potential. On the lower end of the efficiency spectrum, only a small percentage of farmers fall into the 0-20% (2.75%) and 21-40% (0.5%) categories. These farmers may be facing significant challenges in optimizing their production processes, resulting in lower outputs relative to their inputs. Overall, while a substantial number of farmers exhibit moderate to high efficiency, targeted interventions could help those in the lower efficiency ranges improve their productivity and resource utilization.

The graph indicates that while most farmers are achieving moderate to high levels of technical efficiency, a notable proportion is operating at less than optimal efficiency. This suggests potential areas for improvement, such as adopting better farming practices, optimizing input usage, or investing in more effective technologies. By addressing these inefficiencies, the overall productivity and profitability of rice production could be enhanced.

5. Discussion of Research Findings

5.1 Optimization of Input Usage

Capital Usage: The findings indicate that increased capital usage slightly decreases production efficiency, suggesting potential overuse of inputs such as seeds, fertilizers, or pesticides. This aligns with previous studies (Coelli et al., 2005) that highlight the risks of diminishing returns when inputs are misallocated. Improving seed management through precise seeding rates and higher seed quality can reduce wastage and enhance productivity (Pingali, 2012). Adopting precision agriculture techniques may also optimize capital input utilization and maximize output efficiency. Labor Costs: The positive relationship between labor costs and efficiency suggests that skilled labor plays a crucial role in rice production. This supports the argument by Schultz (1964) that human capital investment significantly improves agricultural productivity. Providing farmers with training on best farming practices and ensuring adequate compensation for labor can further boost efficiency. Additionally, labor-intensive methods may be beneficial, particularly in smallholder farming systems, as they improve crop management and quality control (Barrett et al., 2010).

5.2 Addressing Inefficiencies

The high lambda value in the study underscores the significance of inefficiencies in rice production. Inefficiencies may stem from suboptimal farming practices, lack of access to modern agricultural technologies, or inadequate information dissemination (Farrell, 1957). Reducing these inefficiencies requires a multi-faceted approach, including:

Adoption of modern farming techniques such as mechanization and precision irrigation (Gollin et al., 2014).

Improved access to agricultural extension services to enhance knowledge sharing (Anderson & Feder, 2007).

Development of infrastructure that facilitates better transportation and market access for farmers (Dorward et al., 2004).

Policymakers should focus on identifying inefficiencies at regional and demographic levels to tailor interventions accordingly. For instance, supporting water management initiatives or improving rural credit access could mitigate inefficiencies and enhance overall productivity.

5.3 Resource Allocation

The study suggests that reallocating resources to inputs with the highest impact—such as labor—can improve production efficiency. This aligns with findings by Hayami and Ruttan (1985), who argue that resource allocation plays a crucial role in driving agricultural transformation. Potential strategies include:

Subsidies or incentives for labor-intensive but high-efficiency practices such as organic farming or integrated pest management (Pretty et al., 2011).

Providing farmers with data-driven insights on input productivity to inform better resource allocation (Fuglie & Rada, 2013).

Understanding which inputs contribute most to efficiency can enable farmers to make more informed decisions about investment priorities, ensuring better financial and production outcomes.

5.4 Policy Implications

The study provides empirical evidence that can inform policy frameworks aimed at improving rice production efficiency. Key policy recommendations include:

Encouraging optimal seed usage through guidelines and support programs (Byerlee et al., 2009).

Improving labor conditions through education and vocational training programs (FAO, 2017).

Reducing inefficiencies by investing in agricultural infrastructure, such as irrigation systems and storage facilities (Pingali & Rosegrant, 2001).

Furthermore, technology adoption policies should focus on bridging the digital divide in rural farming communities, ensuring that smallholder farmers can leverage modern agricultural innovations to enhance productivity.

5.5 Economic Sustainability

Enhancing production efficiency not only reduces costs but also increases yields, leading to improved economic outcomes, particularly for smallholder farmers. This aligns with the Sustainable Development Goals (SDGs) set by the United Nations (UN, 2015), which emphasize the importance of sustainable agricultural practices for food security and poverty reduction. Key benefits of improved production efficiency include:

Higher profitability for farmers, enabling reinvestment in better inputs and technologies (Dercon & Christiaensen, 2011).

Reduced environmental impact through efficient resource use, supporting long-term agricultural sustainability (Tilman et al., 2002).

By integrating efficiency-enhancing strategies into agricultural policies, stakeholders can promote both economic resilience and sustainable food production systems, ensuring long-term benefits for farming communities and the broader economy.

6. Knowledge from Research

This study contributes to the understanding of agricultural efficiency by highlighting the critical role of input optimization and resource allocation in rice production. The findings emphasize that effective seed management, skilled labor, and access to modern technologies are key drivers of productivity. These insights align with previous research while providing specific recommendations for improving efficiency in local farming contexts. Furthermore, the study underscores the importance of addressing inefficiencies through targeted policy interventions. By identifying factors that hinder production efficiency, such as suboptimal resource use and limited infrastructure, policymakers and agricultural stakeholders can design more effective strategies to support farmers. This contributes to the broader discourse on sustainable agriculture and rural development. Finally, the research provides valuable implications for economic sustainability in agriculture. By improving production efficiency, farmers can achieve higher yields and profitability while minimizing resource waste. These findings support the transition towards more resilient agricultural systems that balance productivity with environmental sustainability, ensuring long-term food security and economic stability.

7. Recommendation

Based on the findings, the following recommendations are proposed to enhance rice production efficiency:

1. Improved Seed and Input Management: Farmers should adopt better seed selection and precise seeding techniques to avoid overuse and improve productivity. Government programs could support farmers by providing access to high-quality seeds and training on optimal input application.

2. Skill Development for Farmers: Agricultural extension services should focus on training programs to enhance farmers' skills in modern farming techniques, resource management, and sustainable practices. This could be facilitated through workshops and technology-driven learning platforms.

3. Enhancing Access to Agricultural Technology: Policymakers should promote the adoption of precision agriculture tools, such as GPS-guided equipment and automated irrigation systems, to optimize input usage and improve efficiency.

4. Incentives for Sustainable Practices: Governments should offer financial incentives or subsidies for practices that promote long-term sustainability, such as organic farming and integrated pest management.

5. Strengthening Market Access and Infrastructure: Investing in rural infrastructure, such as roads, storage facilities, and transportation networks, can reduce post-

harvest losses and ensure that farmers have better access to markets, thereby improving profitability.

6. Policy Support for Labor-Intensive Farming Methods: Given the positive impact of labor on efficiency, policies should support fair wages and better working conditions for farm laborers. Encouraging cooperative farming models may also enhance productivity and reduce labor shortages.

By implementing these recommendations, stakeholders—including farmers, policymakers, and agricultural organizations—can work towards a more efficient and sustainable agricultural system, ensuring long-term benefits for both food security and economic stability.

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